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CONTENTS

"Economics of Village Industries with Special Reference to Construction Industry" by

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Chapter.		Page.
I.	Introduction	1
II.	Economics of Public Works ...	9
III.	Economic Condition of Construction Labour	18
IV.	Economics of Construction Industry	27

CHAPTER I

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Introduction.

Economics is the science that investigates the conditions or laws affecting the production, distribution and consumption of wealth. At the present time, whether we be rich or poor, old or young, man, woman or child, there is scarcely any subject more vital and of immediate urgency than this science of economics.

Text books make us believe that economics is a matter of exports and imports, of the balance of trade, of gold reserves, bank rates, foreign exchanges and other puzzling abstractions remote from the immediate concern of the ordinary citizen. For the vast majority of our nation such matters are quite secondary and not even of academic interest. The reason is that for all practical purposes they are entirely outside their control as are the vagaries of the weather. But with the things that really matter in economics we are one and all supremely interested. Those things are the amount of our incomes and what we do with it, e.g., the rent, rates and taxes we pay, the prices of food stuffs and cloth we buy, the cost of railway and bus fares, firewood, electricity and the thousand and one things we want to

buy for our needs, our comfort or our pleasure. We are greatly interested in increasing the value of our income or reducing the prices of things so that the money we receive will buy more of them, or in other words, in making our economic life easier or more comfortable.

It is unthinkable that we should continue indefinitely to endure with patient resignation, or even to tolerate at all, the present miserable, bitter, and wholly unnecessary struggle for economic existence and the ceaseless troubles, inconvenience, and suffering associated with constantly recurring rising prices, heavy taxation, strikes, lockouts and so forth. The fear of death is a trifle to the fear of unemployment and starvation. The terrible injustice and hardships of modern economic life can quite easily be traced to modern agricultural and industrial life or rather the neglect of agriculture and machinization of industries. The present agricultural, industrial and economic conditions are even more subtly cruel than the worst abominations of the war. We have therefore to get down to the very core of the matter and examine with ruthless penetration the meaning and purpose of agricultural and industrial life, which is the production of the food and things we need, and what is much more important, the consumption of those things, i.e., the methods which enable

the produce to be brought to those who need them.

Industrial magnates in every country have thoroughly specialised in the art of wealth production but have miserably failed in the equally vital arts of its proper distribution and consumption, vital to themselves no less than to the labourers they employ and the public who buy the products of their industries.

Agriculture and industry exist for one primary purpose—to produce food and things for people to use—rice, wheat, vegetables, milk, houses, irrigation works, roads, bridges, railways, food, clothing, furniture, sports, recreations, music and all the other things which make life healthy, useful interesting and above all, enjoyable. Most of us do not care at all about the balance of trade or whether exports exceed imports or vice versa; but what we do care about and ought to care about a great deal more effectively is the price of things in the shops, and how far our money will go. And unless the socalled science of economics helps to give us more money by giving us continuous and equitable employment and to make things cheaper to buy so that our lives may be richer and happier, then it is a barren and unprofitable pursuit and must be replaced by something of real use to mankind.

Up and down the country are hundreds of thousands of shops and agencies anxious to distribute to the public the multitudinous products of farm and factory. In nearly every one of the millions of houses from Cape Comorin to Himalayas are people who want things. All want food and clothing, many want furniture, books, bicycles, toys, glass, enamelware, musical instruments, in fact, almost anything you like to name. There has never perhaps been such a universal want, and such a widespread need for necessities, comforts and luxuries as there is today in the homes of this country.

And yet in spite of all this, **in spite of there being (1) abundance of raw materials, (2) millions of acres of cultivable land to produce food and rear live-stock, (3) men to cultivate lands and convert the raw materials into articles of use, (4) men to distribute the products of the field and industries, (5) an unprecedented demand for huge quantities of what the field and village industries can produce nothing happens.** Millions and millions of acres of virgin land throughout the length and breadth of the country remain uncultivated and millions of unemployed men and women are tramping the streets in the towns or wasting their lives in the thousands of villages all over the country, losing their health, their moral fibre, their self-respect; women and children grow pale

and listless from hunger, and despair; nearly every one is hampered in his usefulness through want of the things he cannot afford to buy and is prevented from enjoying a little of the happines that he might enjoy if he were "better off". And all this merely because there is not enough "work" to engage the people and "money" to go round. Millions of cattle are idle for want of lands to plough and produce to convey from place to place, and these cattle are a burden on the people who own them. Millions of country carts are idle, getting rotten and rusty. The few things that are moved from place to place are carried by trains and motor lorries, thousands of the later having been added to the previous stock when the war ended.

No one can deny these facts; every one knows them. And still nothing happens. We are letting our agricultural and village industrial life go to ruin, and leaving our people in misery, needlessly and with a folly .an colossal as it is criminal.

Is there no way of harnessing the idle land, men and cattle and set going once again the wheels of agriculture and village industries and to end this terrible state of idleness, misery, hunger, want and starvation? How much longer are men and women who claim to be civilised and to be able to reason, going to

endure this intolerable state of affairs, which would be ludicrous, laughably absurd, were it not so pitiful and tragic ?

Is it not abundantly clear, from even the little we have so far read that a foolish system, a vicious system, which permitted or rather connived at the neglect of agriculture and village industries has been allowed to dominate men during the past century, instead of men intelligently shaping and adapting the system to their needs ? Men have become slaves to a series of incompetent administrators who have slowly and steadily, in few decades, throtted agriculture and village industries.

No one but a confirmed optimist will imagine that our rulers, leaders and industrial magnates will of themselves alter the existing system. In this as in all other matters of public welfare, there must be a considerable mass of public opinion clamorously urging its case before our rulers will introduce the necessary measures of reform

The general public need not trouble to understand the somewhat intricate mechanism of finance, of banking or even of book keeping. But what the general public must understand is that the present state of affairs is intolerable that it is easily within the wit of men to improve present conditions beyond recognition, and to abolish poverty absolutely

and entirely, once and for all time. Let the public make up its mind that these things are possible, and must therefore be done.

There will then be plenty of experts with the brain-power necessary to devise all the details of the mechanism of state-craft so as to bring about this end by introducing necessary legislative enactments in the provincial and central legislatures. Intelligence alone will make it sooner; if it is later, then there will certainly be another war, call it civil war or otherwise, or other troubles of a grave nature first.

And now befere I go into the details of economics of village industries with special reference to the construction industry, in the succeeding chapters, I wish to make a personal appeal to every reader who is convinced that the present state of affairs is really bad. Reader, if you love your country; if you love yourself and your wife and children; if you wish well by your fellows; if you hate this curse of poverty which hangs like a deadly pall over our land; if you wish to make this country a happy and comfortable place for all; if you wish to bring back laughter to children, smiles of contentment, good-will and peace to men and women; if you wish to help to release the inexaustible good spirits, the kindliness of heart, the generosity

of feeling, the love of freedom, the courage and energy of our nation; if you wish to put an end to war and strife, and make this land one of peace and prosperity; then do not rest after reading this book, but work to bring these things to pass, study books on agriculture, economics, labour, industries and allied books by able writers; think out these matters for yourself, brood over them, dream of them, plan for them, talk to others, in public and in private, ceaselessly; make the lives of your representatives in the Provincial Assembly and Central Assembly and the Ministers a burden to them until they turn their attention effectively to this, the greatest problem of our age, the removal of the curse of poverty, insist on something being done, and that soon, lest further terrible wars, civil and otherwise, and economic strife ensue and overwhelm us.

We are near the dawn of a new age; there awaits us such an era of material plenty as fills the imagination to overflowing with the wonder of it, if only we shed our present lethargy and taking courage with both hands, ceaselessly strive to reach it. We can easily produce double the foodstuffs we are producing now and we can easily make far more things through village industries than we can possibly use.

To "get understanding" and "action" are the crying need of men today, and through understanding

and actoin, material plenty, that their body may be alive and their souls free.

CHAPTER II

Economics of public works

In this chapter I propose to make a comparative study of public works as practiced by the Government in the past ages and as practiced at present, the causes that underlie the changes noticed between past and present practice and their effect on the eccnonic condition of the people, the mass of people who pay for these public works through taxes, direct and indirect.

The history of a nation is mostly written from a detailed study of the archaeological excavations, ancient and modern structures and monuments. These structures reveal the growth in the individuality, character and the genius of the nation through their artistic and architectural presentations. It is a well known fact that South India possesses a large number of temples which are remarkable for their size and for the enormous wealth of artistic and architectural material which can hardly be found elsewhere. Those who have

had the opportunity to study these temples in some detail can realize not only the value of these ancient monuments for the student of ancient history of the land but also the immense part they played during their construction period in the economic well being of the people. **In the centuries when the construction of these monuments were in full swing, this construction industry employed millions of men and women and their cattle and carts especially during the major part of every year when the agricultural operations were at a standstill.** This industry includes numerous other village industries such as the manufacture of bricks, tiles, lime, pottery, terra-cotta, and the professions of masonry carpentry, smithy, sculpture, painting, etc. Employment in so many village trades and industries depends directly or indirectly upon construction activity. Employment not only in the construction works in the field such as earthwork, masonry, etc., but also in the raw materials industries and those industries producing complementary products is dependant on the volume of construction.

It is not difficult for engineers and statesmen of today to recall the time when such artistic, architectural and monumental structures were built throughout the length and breadth of this country exclusively with the most durable of all

structural materials produced in the locality such as bricks, stone and lime. Ever since the beginning of recorded history of this country till about the end of last century only durable local materials and local labour were used in the construction of every public and private structure such as an office building, temples, mosques, high courts, railway stations, bridges, anicuts tanks, dams and palaces. The history of architecture and the dignity and massive and imposing character of the most elaborate and ancient temples and other structures all over this land afford ample testimony as to the past practice in the use of all simple, beautiful, and durable structural materials produced by local industry such as brick, stone, lime, marble and pottery. They afford sufficient proof of structural and artistic success for such monumental works. On the other hand, being far less expensive than factory made materials such as cement, and steel, their pre-eminent superiority both in strength and beauty, durability and charm is obvious. You can build a palace of brick and stone and it will fittingly represent "The dignity that both hedge a king" and you can build a cottage of brick and stone which as fittingly expresses the ryots' homely comforts and enjoyments.

The Archaeologist has found enormous evidence, in his excavations all over this country, that bricks, stone and lime were used thousands of

years before the earliest recorded date of the history of this country. Brick and stone have attended the course of humanity from its most primitive times and offered themselves for the most distinguished uses.

Even during the first few decades of the 19th century, bricks stone and lime were used in all public structures under all conditions as is evidenced by the fort wall around Fort Saint George, Central Station, High Court and old bridges in Madras, the Sulochana Mudaliar Bridge across the river Thambraparni at Tinnevelly and the Godavari anicut across a deep perennial river.

An analysis of these and other old structures show that structures of brick and stone in lime or surki mortar withstood the action of the elements—wind, weather, and sun—for centuries and under most conditions such structures continue to increase in strength and durability as their life increases. The history and present condition of every type of temple, palace, fort and other public structure in our cities and bridges and irrigation works of enormous magnitude such as the Godavari anicut, Kannambadi dam and Periar dam, afford ample proof that these local materials built with local labour meet their requirements most satisfactorily.

An example of a beautiful and durable bridge across one of the perennial rivers in South India, the river Thambaraparani, is the Sulochana Mudaliar bridge built in 1844. It consists of eleven elliptical brick arches of sixty feet span with a roadway twenty-four feet wide—a width allowed in a bridge before the motor car was invented, but rarely met with in these days of fast motor traffic. The upper and lower faces of this bridge are ornamented with rows of coupled doric columns standing on the ends of the piers and supporting an entablature and balcony above. The parapets are open balastrade work finely polished with shell lime presenting an appearance of marble, and giving to the whole structure a grand and imposing effect. The foundation wells are of dry brick filled with brick jelly—a design that would knock away the senses of the modern engineer if he be directed to build another bridge with similar foundations.

It is only since the end of last century these local materials have been replaced gradually by iron, steel and cement, and the local labour was pushed out to give way to concrete mixers, excavating machines and stone crushers. In the early days of the use of these materials and machines they were used for special requirements such as well curbs for foundations in bridges where rapidity of execution was deeme

essential. However, as time went on there developed among engineers an impression that strength and rapidity were the only requirements in materials and labour. The practice of using steel and cement for the superstructure of bridges when the piers where built of stone and mortar or brick and mortar held the field for a while. Later on, the masonry piers gave way to cement concrete piers and lastly we find in several cases of bridge construction, the whole foundation and pier being formed of slender brittle hollow cast iron cylinders. Thus, the displacement of almost every local material and local labour in the construction of public structures and partly in private structures by iron, steel, cement and machinery has developed to such an extent that the modern engineers and architects responsible for their design and construction have deluded themselves into the belief that they have thoroughly succeeded in developing structures which they consider orderly, consistent, and progressive from a practical point of view. But unfortunately these structures are quite hopeless in respect of beauty, and are shortlived and very uneconomical from a national point of view. These modern structures said to have been designed to meet the secular and practical conditions represent the unimaginative and uncharitable character of the people who design and build them unlike the old structures most of them dedicated to the immortal

gods, the decorative character of which was inspired by religious emotions, and charitable, and economic considerations.

From year to year this drifting towards "mechanical perfection" went ahead at a rapid rate and the economic depression in the country has deepened to such an extent that there is widespread misery alround. This "mechanical perfection" has not carried along with it a corresponding progress in grace and beauty of design and construction. The machines and machine made products have lightened human labour, but added to human drudgery and poverty of the masses. They have robbed the worker of the sense of craft and also of his sustenance. Where ten craftsmen were employed hitherto now one machanic does their work. As the modern construction work is mostly monotonous, it exhausts the body without interesting the mind. In modern machine-made construction there is practically no room for any individual skilful creative work which alone would develop intelligence, and character of the nation.

One of the chief causes for such drifting towards "mechanical perfection" is the modern trend in engineering design and construction caused by the present tendency towards specilization in engineering studies and the failure to

impart the elements of national economy as applied to engineering. The ideal college in the education of an engineer is not a trade school. The education should be largely general, and special branches, should be so handled as to broaden and not narrow the outlook and knowedge of the student. The most important acquirement for the engineer is not a detailed knowledge of engineering principles, formulae and technical methods—except where such matters are needed for immediate use—but the ability to ascertain and apply the correct priciples and data when needed for professional purposes.

Most of the operations of public works result in transfers of huge amounts of money, in other words, purchasing power, from public authorities to the public and by way of taxation part of the money flows back again to public authorities or rather the Government and the rest to industrial and other concerns. As a result, changes take place in the distribution of that wealth among individuals and classes. Improvements in distribution of that wealth would result in reducing the great inequality among the poorer sections of the community. Such a reduction in inequality in desirable as it offers the maximum social advantage to most people in the community, by gradually removing the curse of poverty.

As the public works official who spends a decent part of the nations revenue is one of the trustees of national wealth for the future no less than for the present, he should prefer a larger social advantage in the future to a smaller one today. **As one of the authorities of public expenditure the engineer has to decide which methods of design, construction, maintenance or reconstructions will produce the maximum social advantage to the community whose money he spends.** He must distribute the money of large public works on a reasonable basis between the active business interests and the labouring classes by utilising most of his expenditures for human labour and for the development of productive enterprises of the most durable structural materials and equipment manufactured by the people who meet his bills. All these are well accepted canons of economic improvement and in so far as the operations of public works expenditure can bring about improvements on the whole, such operations are justified and are called truly economical.

A thorough study of the problem of economic design and construction at the present time is necessary to effect the revival of local industries such as the manufacture of bricks, tile, lime and pottery and the professions of masonry, carpentry,

smithy, sculpture and painting and thus improve the economic and moral condition of the people.

The design of engineering structures with local materials and their construction with local labour is a matter of intimate concern to the engineer; its problems are his problems; its strength is his prosperity and the well being of the people.

CHAPTER III

Economic Condition of Construction Labour.

The construction industry is practically a sheltered industry; there need be no foreign competition, and on the other hand it cannot expand by entering other markets abroad. This industry is distributed largely according to the distribution of population and industry. It is one of special interest since employment in numerous trades and village industries depends directly or indirectly upon construction activity. Employment not only in the construction trades themselves such as earthwork excavation, masonry, carpentry, and smithy, but also in the raw materials industries and those industries producing complementary products is dependent on the volume of construction works. Employment in con-

struction industry is normally subject to seasonal fluctuation because construction activity depends on weather conditions and social factors. Unfortunately in this country, it depends entirely on the capacity of the engineer who is responsible for the design and construction of public and private works, and who, left practically uncontrolled by the politician or statesman, has done his best, though unconsciously, to kill village construction industry and displace labour by construction machinery.

The men employed in construction industries in England, America and other European countries are very well organised. As an effective practical example of good organisation and collective bargaining making for efficient service to the community, the organisation of the construction (building) industry stands out as one of the best in the industrial life of Great Britain and gives to the employees better standards of work and of life and increasingly more security.

The National Federation of Building Trades Operatives (i.e., labourers skilled and unskilled employed in construction industry) in Great Britain includes among its affiliated societies numerous building trade unions, plumbers and glaziers

societies, engineers union. road makers societies, union of municipal workers transport workers unions, carpenters, smith, sawers, machinists, and other trade unions. The individual affiliated societies appoint their own representatives to the national organisation. The objective of the Federation as of its component parts may be stated broadly to be the safeguarding of the interests of the operatives, the improving of their conditions, wages, and hours of labour, collective bargaining with the employers and the correlation of the needs of the whole community.

Wages are fixed in the form of hourly time rates and these rates could be varied periodically in accordance with the movements in the level of the cost of living as ascertained and recorded by the Ministry of Labour. Different localities are classified into 'grades' in each of which a distinct rate is fixed, overtime rates are laid down upon a national basis and detailed regulations are made for out-of-town and for travelling allowances. The controlling body in these matters is the National Joint Council of the building industry which consists of representatives both of the employers and the labourers, skilled and unskilled.

Wages rates fall into three categories; standard, exceptional and differential, standard rates

are the rates applicable to craftsman generally in each of a number of specified grades into which districts are classified and are reviewed at the January meetings of the Council. Changes in the standard rates are founded upon variations in the cost of living in accordance with the scale set out in an agreement concluded by the Council, which is binding on both employers and employed. Exceptional rates are those which apply for a prescribed period instead of the current standard rate in a definite district. Exceptional rates are designed to meet the position where a large work is to be carried out in a rural district and where the standard rate of wages is insufficient to attract the number of operatives required to carry out the special job. The exceptional work completed, the district reverts automatically to the permanent grade rates.

The detailed classification of districts for the purpose of wage rates is, it is claimed, one of the most striking results of collective bargaining in the industry. There are nine grades with a wage difference of one halfpenny per hour for craftsmen in the standard rates as between each grade and the next one above or below it. The London district has special rates; within a twelve miles radius of Charing Cross the rate for craftsmen is $1\frac{1}{2}$ *d.* per

hour in excess of the current grade A rate; within between twelve and fifteen miles radius of Charing Cross the rate is 1 *d*. per hour in excess of the current grade A rate. Both in London and in the districts, in all nine grades, the hourly rates of wages for labourers are in all cases 75 per cent of the standard rates for craftsmen.

Variations in grading of districts are only permitted after the previous grading has been in operation for there years. Applications are dealt with regionally and subsequently by the Grading Commission of the National Joint Council; which reports and recommends at each January meeting of the Council. In grading a district the Council takes into consideration the size, nature and position of the town, local living conditions (including rents, local authority charges and relative levels of prices), transport facilities, and the amount and type of construction work in the locality, as well as the rates of wages in the chief local industries.

There are National Conciliation panels and National Joint Emergency Disputes Commissions to deal with disputes between employers and employees. The parties undertake to exaust every means of effecting an amicable settlement before resorting to direct action, and not to instruct their

members to strike or lock-out without complying with all the agreements in existence and giving customary notice to terminate the employment. If the Regional Commission is unable to find a solution for a dispute, a National Commission is at once convened, and its findings become binding as soon as given.

Basic wages are subject to the operation of the cost-of-living index figures under the sliding scale provisions of the agreement. In the inner London area craftsmen receive 2 *sh.* an hour, labourers 1*sh* $6\frac{3}{4}$*d.*In grade A distincts craftsmen receive 1 *sh.* $10\frac{1}{2}$ *d.* an hour, labourers 1 *sh.* $5\frac{3}{4}$ *d.* In the lowest graded rural districts craftsmen receive 1 *sh.* $6\frac{1}{2}$ *d.* an hour, labourers 1*sh* $2\frac{3}{4}$ *d.* (all as at 1st June 1941). The general working hours are 44 hours a week in winter and $46\frac{1}{2}$ hours in summer, but in districts including London, there are "variation amendments" whereby the hours are 44 per week all the year round.

Speaking at the annual conference of the National Federation of Building Trades Operatives at Douglas, Isle of Man, in June 1937, Mr. George Hicks, M.P., the president said:

"I believe we are on the eve of having the opportunity to realise the greatest reform the

Building Industry has known. I refer to the proposed scheme for the payment of time lost through inclement weather.

"This will be an Insurance scheme jointly contributory and applicable to all the employers and operatives in the Building Industry.

"The scheme will be part of the unemployment Insurance Act.

"We had hoped to have been able to state the precise time for the practical operation of this scheme.

"The scheme will be under the control of a Joint Board of Employers and operatives.

"At least fifty per cent of the hardship and handicap of wet time—the immemorial curse of the Building Industry—will be gone. In this way a great step forward will have been made to stabilise working conditions."

Owing to the war and the many new problems associated with it, this scheme has been held in abeyance. As there is now a Labour Ministry in England, it is expected that this scheme will be put into effect as early as possible.

In this country, unfortunately, like numerous other ills in society, the craftsmen engaged in village construction industry and its numerous

subsidiary village industries such as brick making, quarrying, stone breaking, lime making, pottery, timber sawing, carting materials, paint manufacture, etc. etc., are not at all organised into any kind of union. But the craftsmen engaged in factories producing cement, and steel in this country have got their own trade unions to look after their welfare and for collective bargaining with their employers, similar to the unions of railway workmen, postal labour, etc.

The rates of wages for craftsmen in the construction industry are standardised by the Public Works Department of each Provincial Government and these rates vary slightly from district to district and are operative for a year. But these rates are not subject to the operation of the cost-of-living index figures and as such, changes effected in the schedule of rates have practically no relation whatsoever with the change in the cost-of-living. Most of the craftsmen engaged in public works are employed by contractors and as these contractors are not governed by the Government schedule of rates they bargain individually with each labourer and seldom pay even the wages fixed in the schedule of rates.

As such, the economic condition of the millions of men and women employed in this industry

is deplorable and the first step to be taken towards improving their economic condition is to organise them into taluk unions, district unions and provincial councils, conduct a detailed enquiry into their living conditions in each district, fix necessary grades of wages and working hours to all craftsmen and have necessary legislation passed in the Provincial Assemblies for enforcing the prompt payment of the wages fixed. **It is the primary duty of the Ministry of Labour in each province to set up necessary machinery for organising the labour in construction industry with the least delay possible. The other Ministries should co-operate in providing employment for all the labourers and craftsmen in the province by deliberately avoiding the use of labour saving machines in all their construction activities in public works, roads, buildings, irrigation works electrical and other public utility schemes.**

A scheme for the payment of time lost through inclement weather should be formulated so that this immemorial curse of the Construction Industry may be removed for all time.

Finally, the question of housing conditions of these people should be taken up and model dwellings of proper standards suitable for the various craftsmen of the industry should be erected on a five or ten-year plan, to house all the

craftsmen in this industry. The close connection between bad housing and ill-health, and between ill-health and a high poor rate needs no emphasis. At present most of the dwellings of these labourers are not ventilated, they literally swarm with vermin, and are scenes of filth, discomfort and disease. Public economy demands that proper and sanitary conditions are created by the state for all people who are unable to build their own houses and are unable to rent decent quarters at economic rents.

CHAPTER IV.

Economics of Construction Industry

The economic problems which commonly must be considered by the Engineer in designing and carrying out construction works of any kind—public works or private works—may be classed as

(a) Economic selection,
(b) Economic execution and management,
(c) Economic expediency, and
(d) Economic worth.

In most cases of public and business structures the business factors or economic worth are primarily more important than those of design

and construction, i.e., economic selection execution and management, because, a project that is not a financial success or that fails to give an adequate tangible or intangible public benefit to the community which finances its execution, cannot be regarded as a success although it may be successful from a structural standpoint. The knowledge, judgment, and experience required for such solutions are much more complex, intricate and extended than are required in engineering design and construction.

Economic Selection

Economic selection means the determination of the most economical design for accomplishing a given purpose. This is the problem in economics most common in engineering practice. It includes the selection of the best type of materials for construction and the best and economical design to fulfil certain requirements. Unfortunately, it is the toughest of all problems in engineering as the human element, especially the element of bias in human conduct plays an all important role in its solution. That all men are to a greater or less degree biased in their judgment of themselves and of others and of all problems and conditions with which they come in contact is established by common experience.

The engineer and architect like any other individual is not free from bias and it shapes the design selected by them for the problem which they are asked to design and build.

Personal Bias

This bias is due to their individuality, their association, their local and individual experience, their education and special knowledge, and above all their personal interests. That this bias is possessed by others and injuriously affects their judgment is easily recognised. But it is more difficult for the individual to recognize such bias in himself. It is however most important for the engineer to recognise his own bias and to provide for it by elimination as far as possible, and by the same factors of safety which he applies to other uncertainties met with in solving his engineering problems. To acquire this knowledge is the most difficult in the practical life of the engineer.

Bias of Special Knowledge

Special knowledge and a special experience in a limited field of engineering, unless accompanied by a capacity for a broad consideration or outlook on the problem on hand and a considerable knowledge of collateral subjects, are apt to involve a prejudice or bias in fovour of the

application of such special means to the solution of all problems to which such means can be applied. The specialist naturally appreciates the full value of his speciality and the advantages that accrue from its application. Normally, he is less informed in other special methods of solution of his problems, and is apt therefore to give undue weight to the advantages which he knows his own speciality to possess. The hydraulic engineer is apt to overrate the advantages of water power and to underrate the contingencies of its construction and maintenance. **The project engineer can only visualize increase in cultivable lands in terms of dams, canals, regulators and falls and is unable to comprehend the potentialities of a series of small and big tanks in a catchment in throwing open enormous acreage of land for cultivation.** The steam engineer is apt to over-estimate the value of the use of steam power in the solution of all power problems, and the electrical engineer, recognising the advantages of electrical generation and transmission is apt to consider only electrical methods in power applications. The mechanical engineer in charge of irrigation works can think only of mechanical means for impounding and diverting greater quantities of water for irrigation purposes such as fitting up falling shutters on crests of anicuts with its perpetual maintenance trouble constant atten-

dance and recurring expenditure, a problem which could be solved very economically by constructing a high co-efficient crest over a major length of the anicut. In each case the advantages of other methods may be overlooked and the problem solved on individual preference and information, and not by the method which would prove the most advantageous, if all conditions and methods are fully weighed and considered.

In the correct solution of any problem, all of the methods by which it can be solved are deserving of the fullest and most careful investigation and consideration, for only by such means can the best solution be found; and the engineer who is desirous of securing the best and most economical solution of the problem entrusted to him must give the most careful consideration to those methods with which he is least familiar, for only by so doing can he hope to accomplish the best and most economical results.

Bias of Personal Experience

Personal experience should give the engineer his most useful and exact knowledge, provided such experience is properly considered and digested. The fact that the knowledge so acquired is the most exact and valuable in his possession is apt to give it undue importance in the solution

of other problems with which he has to deal. A successful engineering achievement, the product of ideas well matured, and of plans carefully prepared and well executed, which has resulted in the creditable solution of an intricate problem may rightly lead to the future application of similar methods and designs to problems of a similar nature. Frequently, however, there is a tendency for the successful designer to endeavour to adjust the conditions which prevail in a new problem so that they may be solved by the methods successfully adopted previously rather than to adjust the plans to meet the conditions as they exist. This tendency frequently results from a natural indolence to plan and adopt new methods to a problem where a successful solution, which has stood the test of practice is immediately available; and in many cases, the plans bear evidence in themselves by the possession of certain common features of the sources of their origin, and the disinclination to consider each problem on its individual merits. Evidence of such a tendency is frequently met with in project designs, building construction and bridge designs. We occasionally meet with an extreme form of such indolence in the shape of project reports and designs which bear evidence of their origin in other project reports and designs which strangely

have not even stood the test of practice for the simple reason that they have not been carried out.

Bias of Local Experience

The normal conditions which obtain in any locality must of necessity modify the successful solution of every local engineering problem A professional man who has successfully met the various problems as necessarily modified by local conditions within the range of his practice, has therefore to readjust his ideas and to modify his plans whenever he is called upon to solve a problem under circumstances where the local conditions differ to any considerable extent. For example, the flow of streams differs radically not only on account of the difference in rainfall on the different drainage areas, but even more largely on account of the geological and topographical conditions; and the engineer who has given special attention to one stream must use special care when he considers construction which is to be carried out on another stream for which the conditions of flow may be radically different.

In the matter of electrical supply for light and power, the demand per head varies greatly in different parts of the same country and in cities

of various sizes, even closely adjoining. Local factors greatly affect the cost at which work can be done. In the larger cities, the existence of labour unions, which usually involve higher wages and shorter hours together with the extra cost involved by street obstructions and other similar factors, ordinarily greatly increase the cost of work over that for which similar work could be done in communities where the market for labour is not modified by such conditions, where traffic and obstructions are less serious, and where many other conditions are favourable to cheaper construction. It is common observation that men familiar with only one set of these different conditions commonly fail to agree on the cost at which work can be done in some third place where neither has had actual experience. The city contractor who occasionally tenders for work in the country is usually unsuccessful as his experience with the high prices of the city prejudices his judgment, and the contractor familiar with the work in the moffusil commonly learns by dear experience the extra cost involved when he attempts to transfer his operations to the larger cities. These difficulties can be overcome by freeing the mind of purely local influences and by a detailed study and consideration of the new conditions.

Bias of Association

Almost every problem is capable of a variety of solutions although there is only one solution that can be the best when all things and matters are considered. Almost every question can be regarded from several points of view, and the correct answer is not always clear or evident. Association will normally establish the point of view from which the individual will consider any question which is called to his attention. The most common exercise of this tendency is found in the unfair treatment of contractors by engineers who supervise the construction of works. There is a constant tendency to inflict unjust requirements and to require unwarranted expense specially in meeting the given specifications or there is the other extreme wherein the engineer permits the contractor to do bad quality of work, the later conduct being met with in public works. In private works, the engineer is too apt to see matters entirely from the view point of his client and to fail to exercise that impartial judicial attitude that his professional position demands.

In the work of valuation of properties where the Government or a Municipality contemplates the acquisition of a property the Government or Municipal engineer is almost certain to assume

the point of view which is most favourable to the side which he represents. This may not be due to any desire on his part to be unfair or biased, but is normally what is to be expected from the action of the human mind. Such valuations when taken to a Court are set aside with various comments by the judge, who endeavouring to be entirely fair and equitable in his findings and even appreciating his own inclination to bias in these matters, is prone at times to err on the otherside by overrating the property and issuing findings that are more or less unfair to the Government or Municipality. Such occasional judgment, however, does not disprove the general proposition that in the main the tendency is to favour the client or the party whom the engineer serves, but it emphasizes the fact that the fair minded man is not always able to bring in an equitable finding in the face of his association and the personal proclivities of those by whom he was selected.

The same tendencies are more fully emphasized by the expert witness in a witness box. There the personal bias of the witness is often accentuated by the endeavour of the opposite party in the dispute to confuse or confound the opinions expressed. In some cases these idiosyncrasies are so pronounced and are carried to such

an extent as to give even the appearance of dishonest intentions, to which they are sometimes closely related as to be almost indistinguishable and may range from mere prejudice to actual dishonesty in many lines of engineering work.

Bias of Personal Interest

It is important that the engineer should free himself as far as possible from the bias of personal interest which is a constant menace to sound judgment. No matter how conscientious a man may be or how much he may endeavour to arrive at judgements which are thoroughly sound, he is constantly in danger of not attaining the results desired if his personal interests are in any way involved.

The engineer who is out of employment may, on account of his personal necessities, be greatly tempted to accept commissions or employment which are entirely beyond his experience or ability. The reports of such engineers on works or projects are often unduly optimistic for the reason that the engineer making the report is unconsciously influenced by the fact that a favourable report will mean the execution of the project and his employment in its design, construction or supervision.

An engineer having a patent for some methods or process is constantly in danger of advocating this method, when it is at all applicable, and this from no dishonest motive but on account of the fact that he has become so impressed with his favourite process that he gives it a value to which it is seldom entitled under all conditions of application, e.g. some of the patented timber treatment processes and patented concrete piles. It is essential therefore that the individual endeavours to eliminate so far as possible any personal interest which he may have in the problem, except the interest of its correct solution. If its solution on certain lines involves a profit to himself, such profit can be of only the most temporary and unsatisfactory character if it does not also involve the greatest possible success.

Structural Requirements

The three chief considerations which enter into every structural design are.—

(1) Utility,

(2) Strength, and

(3) Beauty

For economic selection, devoid of the several biases enumerated above, it is essential that the designer should have a thorough knowledge of these three elements; utility, strength and beauty, as they affect national

economy, i.e., the economy of the society to which he belongs, the society at whose expense and for whose benefit he designs the required structure. Utility largely depends upon the skill, genius, imagination, intelligence and courage of the engineer or architect.

Utility

Utility is such an arrangement of the various parts of the structure as to serve the purpose, public or private, for which the structure is erected, with the greatest efficiency. For instance, in an anicut the design and location of the scouring sluices, and the relative position, direction and level of the head sluice of the irrigation channel taking off from that anicut, have the greatest bearing on the continued efficiency of the channel by keeping it comparatively free from silt deposits, which is essential for continuous and peaceful cultivation of the lands under the channel.

When the structure is a home, it should be so designed and built as to appear to be more than an inanimate object, a mere shelter from wind and weather; it should possess a personality, fitting to its owner and of infinite and continuing delight to him. It should express and fulfil its function with appropriateness and unity of character and

it should be an enduring monument in so far as it is possible to make it within the limits of available materials and financial resources.

Taking another example of a component of a structure, e.g., the kitchen in a dwelling house, it should be compact and conveniently arranged so that the household work may be done with the fewest steps and least drudgery, the fireplace should have a real smoking chimney, the distance to the source of water, and the steps taken to reach the stores and fuel should be the least and the location of the dining room with reference to the kitchen should be such that the menu is not announced to the diners by its odour finding its way to the other rooms in the house.

Strength

Strength is such durability as justifies the care and expense involved. This depends on the skill of the engineer or architect employed to design a structure and primarily on the nature of the materials he chooses for building the structure. Unnecessary strength, such as broader foundations than structural calculations call for, results in an uneconomic structure. During the past few decades, the false idea that masonry of high tensile and compressive strength is necessary in the design of every structure has been over-em-

phasised, much to the detriment of the development of economic and durable structures. Even the weakest of structural materials used in construction, such as common brick built in mud or lime mortar develops sufficient strength with a reasonable and necessary factor of safety to serve all ordinary and practical purposes.

Strength is not necessarily indicative of durability or weather resistance. Unless strength is permanent little benefit is derived. For instance lime masonry gains in strength as lime carbonates. Although carbonation initially is quite rapid, the process continues for years.

Beauty

Beauty is such attractiveness as delights the eye, satisfies the artistic requirements of harmonious form and colour and expresses the material and moral well being of the people. In the case of industrial structures the elements of strength and utility are principally sought and rigid economy plays a dominant role, affording little latitude for the creative imagination to cloth the design with beauty. Little more than a working knowledge of mathematical principles of structures and building processes and costs is required to assemble a weather proof cover for housing such purely industrial plants. But all residences and public structures so placed as to come within

the public view from business or residential streets, public places of resort; or highways, should be and can be made beautiful within the limits of reasonable cost. An example of a beautiful bridge built in 1844 is the Sulochana Mudaliar Bridge across the river Thambraparni near Tinnevelly, the architectural features of which created in pure shell lime and brick, was described fully in page 13 of this book. The upper and lower faces of the bridge are ornamented with rows of coupled doric columns standing on the ends of the piers and supporting an entablature and balcony above. The parapets are open balastrade work, finely polished with shell lime, presenting an appearance of white marble, and giving to the whole structure a grand and imposing effect.

To embellish a design with beauty, the engineer or architect must have the imagination to conceive and the skill to delineate and describe the clothing of an architectural idea in forms that are beautiful—beautiful first and principally in their mass, beautiful and harmonious in their proportions and materials and beautiful in all details and embellishment. And he must have the courage to study the problem until the foregoing requisites are satisfied ; the courage and the tact to dominate and clarify all the situations

which might otherwise give rise to controversy in order to fulfil the purpose for which his professional skill and knowledge were sought; the courage and enthusiasm to exact of himself and of his various collaborators the best of which each is capable. Besides all, must lie the architects' good taste, ever alert in its discrimination against vulgarity or ostentation; always keen to choose simplicity in design, inherent excellence in material and sincerity in workmanship.

Brick and Stone

An analysis of all data available since the dawn of civillsation shows that structures of well burnt brick and stone in lime or surki mortars have stood the action of time, wind, weather and moisture, and continued to increase in strength as the life of the structure increased. There is nothing new in this eminently satisfactory performance of bricks and stone, as is evidenced by the history of every type of ancient and modern structure such as the ancient temples, palaces and forts, and the law courts, colleges, university and other public buildings in our cities, and irrigation works of enormous magnitude such as the Godavari anicut, and the Kannambadi dam.

Bricks and stone may well be called everlasting materials, because, they neither burn nor decay. Their

history affords sufficient testimony as to their enduring character under all circumstances. The upright walls and domes of brick and stone after any conflagration stand as solemn witnesses of their structural worth. Brick and stone, it must be remembered, are fire proof, not merely fire-resisting. In conflagrations, even concrete, though unburnable, will crack or disintegrate, while iron and steel will warp and twist, but well burnt brick face the fire and come through unscathed. Thus it is seen that brick and stone alone, give the greatest salvage value, whether the building be affected by fire or by time.

Time effects great changes in the requirements of the people during the successive stages of their evolution. Witness the different conceptions of the requirements of a dwelling house we, of this generation, have, and compare them with the ideas held by two or three generations back, and witness how the older buildings are being dismantled and rebuilt in order to conform to the latest ideas and new requirements. All such remodelling or reconstruction of older structures is possible because of the fact that they were built of bricks and stone. Had they been built of cement concrete – plain or reinforced – such remodelling would have become impossible within economic limits.

Above all, it must be remembered that bricks and stone, like lime, surki and timber are products of pure village industries and unlike the factory made products such as cement and steel, the manufacture of bricks and similar construction materials by village industries and construction of all structures, public and private, using local labour, help to lift the economic condition of the masses to the greatest extent possible.

Lime Mortars

The properties of mortar which have the greatest influence on the production of durable masonry are plasticity, adhesion, elasticity, minimum volume change after hardening, time of hardening and finally strength.

Lime is the most plastic of all cementing materials used in masonry and concrete and is universally recognised as such both in the laboratory and the field during the past several centuries.

By adhesion is meant the ability of the mortar to adhere to the building unit, e.g., brick, stone, and stone jelly. Sabin states "in a mass of masonry a failure is more likely to occur in adhesion than in cohesion". This is equivalent to saying that the permanency of adhesion is a more important consideration than compression strength. Unless a mortar adheres firmly to the masonry units such as brick and stone and at the

same time permits readjustment due to volume changes in such units under varying stresses created by high wind pressure, changes of temperature and moisture, it must necessarily tear loose and crack and craze within itself.

The best evidence that mortars containing a high percentage of lime possess these desirable qualities is found in the practice of the builders of large structures such as temples, their gopurams, dams and bridges during the past several centuries and in modern times it is evidenced in the standard practice of large number of builders of huge radial brick chimneys in America. The sway of a brick chimney 375 feet high and 5 ft. diameter at top, has been measured to be as much as two feet on each side of the centre line of the chimney, when it is under the force of an eighty mile wind. The high inside temperature causes the inner rings of bricks to expand which subjects all mortar joints to high tensile and shear stresses. From this, it is evident that there are no more severe conditions imposed on masonry of any kind than in tall chimneys. These conditions require a mortar that is tough, elastic and adhesive in the extreme. It must permit movement of the individual bricks without cracking within itself, and without shearing or tearing loose from the bricks. A mortar composed of two parts of lime

one part of cement and five parts of sand by volume, has been found to best fulfill all of the requirements imposed upon it. The high proportion of lime imparts the necessary elasticity and adhesiveness to the mortar, properties regarded as essential to the permanance of the chimney.

Excessive volume changes accompanying the alternate wetting and drying of mortars after hardening are responsible for the development of cracks due to the breaking of the mortar bond. Such conditions generally obtain in structures built in South Indian rivers, most of which are not perennial, and also in outer walls of structures in rainy localities. The expansion and contraction due to such changes in moisture content are far greater than the change in volume produced by normal fluctuations of temperature. Lime has been found to be the only cementing material having a negligible volume change sudsequent to hardening, it being almost the same as well burnt brick, under repeated wetting and drying. Therefore lime mortar does not crack or become loose. But common experience shows that plasters composed of pure cement and sand works loose from the masonry or concrete floor after some months or years on account of its being

less adhesive and liable to considerable volume changes when subjected to constant wetting and drying.

A mortar which sets too quickly is sometimes dangerous where proper supervision cannot be guaranteed. Delays frequently occur in practical construction, during which such a mortar acquires an initial set. It is then often retempered, rather reworked with a trowel, resulting in a mortar of very poor quality and liable to cause cracks and leaks. Pure lime mortar shrinks as cement mortar but it does not harden appreciably during such initial shrinkage. When the initial shrinkage of mortar is accompanied by quick hardening, cracks occurbetgween the mortar and the units of which the masonry is composed, e.g., bricks or stone. It is evident that any contraction in hardened mortar even though it be of very small magnitude is far more destructive to the bond or adhesion than contraction in mortar which occurs prior to its becoming hardened.

Under average drying conditions the initial shrinkage of lime mortar is practically over at the end of forty-eight hours. When bricks or tother units absorb the water from the wet mortar his time is reduced. To prolong the time taken,

for such initial shrinkage, bricks are soaked in water before use so that that they may not absorb the water from the mortar and for some time the masonry is wetted. Subsequent to its initial shrinkage there is practically no expansion or contraction in lime mortar of sufficient magnitude to disturb the bond or adhesion in the masonry. This constancy of volume under all conditions accounts for the fact that lime mortar remains bonded with bricks for ages.

Strength of Mortar and its Influence on Masonry Strength

The idea that mortar of high tensile or compressive strength such as cement mortar is necessary in the construction of masonry and for plastering and pointing of all structures big and small, permanent or kutcha, has been overemphasised by the modern engineer, much to the detriment of the village industries pertaining to quarrying of lime stones and shell and manufacture of lime from them. This is all the more tragic when it is remembered that even the weakest of mortars normally used in construction develops sufficient strength, with a reasonable factor of safety sufficient for all ordinary purposes.

As explained already, strength is not necessarily indicative of durability or capacity for

weather resistance. Unless the strength is permanent, but little benefit is derived. Lime mortar gains in strength as it carbonates. Although carbonation initially is quite rapid, the process continues for years. Kempe's year book of 1944 gives the following in page 344 "Cement mortar is best where great strength is required a short time after completing the structure but where a longer period of hardening is permissible, lime–trass (surki) mortar is cheaper and equally durable". In 99 per cent of all construction work great strength is not required in a short time and as such there is absolutely no justification for using cement mortar for such structures. It is really tragic to see that in masonry dams like the Mettur dam which took several years to construct, cement mortar has been used in preference to cheaper surki mortar, a product of the village industry which as advocated by the original designers and thus several crores of rupees were diverted to cement manufacturing firms and in railway freight for conveying the cement to Mettur.

An analysis of available data shows that strength of a brick wall or pier of given dimensions and construction detail is a function of—

(1) The physical characteristics of the brick;

(2) The class of workmanship employed in laying the bricks; and

(3) The properties of the mortar used.

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Urbach and Hans say in "Strength of Bricks and Masonry" as follows:—"Although the use of a cement mortar instead of lime mortar resulted in a compressive strength of 368 lbs. per square inch (28 days) while the compressive strength of the lime mortar was only 75·4 lbs. per square inch, the strength of masonry with the two mortars was 2,020 and 1,337 lbs. per sq. inch respectively, that is, substituting cement mortar for lime mortar resulted in an increase of 390% in the strength of mortar while the substitution of cement mortar in the masonry caused an increase of only 50% in the strength of masonry."

It must be remembered that the strength of masonry is influenced to a far greater extent by the strength of the units, such as brick or stone, than by the strength of the mortar. A study of all the test data on brick masonry made available to the United States Department of Commerce Building Code Committee in its preparation of "Recommended minimum requirements for masonry wall construction" leads one to the above conclusion. The graph below gives a typical test data showing the relative strengths of various mortars, i.e., lime and sand, lime-cement and sand and cement and sand, and strength of brickwork at an age of 28 days built with these mortars. A study of this and similar graphs will

show that masonry of great strength can be developed through the use of high strength brick and mortar of low strength than can be developed with low strength brick and mortar of high strength.

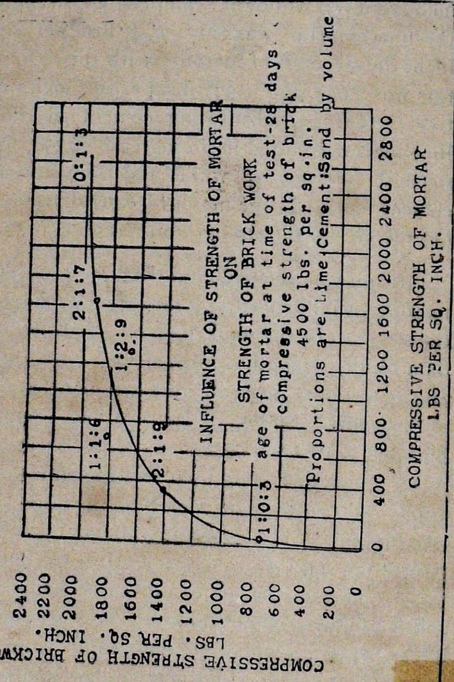

FIG-1

The lowest strength of lime mortar in present day use has ample strength with the necessary factor of safety to meet most constructional requirements. Far more desirable properties in a mortar than strength are workability, adhesion, elasticity and minimum change in volume after hardening. These factors alone determine whether or not a wall will resist driving rains, and wind; in other words, the permanence of the masonry.

Efflorescence

A common defect in poorly built masonry is efflorescence. Three factors produce it. They are: soluble salts, water and passages through which water reaches the salts. The salts which cause efflorescence, chiefly the sulphates of calcium, magnesium and sodium, are all soluble in water to some extent. Chlorides in the form of calcium and sodium salts are less troublesome. These salts are dissolved in water which finds its way into the interior of masonry walls through capillary attraction, holes in poorly filled joints and cracks which develop in the structure as a result of stresses, strains and poor adhesion of mortars. The degree to which capillary action takes place is a matter of small concern as compared with the two other sources of water penetration. After dissolving in water, these

salts are carried in solution to the exterior face of the wall where they crystallise and deposit on the face as the water evaporates The process of crystallisation produces cracks in the mortar and drops it down.

Building materials such as bricks, lime, cement, sand and even water contain these salts in varying degrees. Even traces of these salts are capable of leaving an efflorescent deposit when the two other factors, i.e., water and an adequate passage are present. When bricks are made from clays containing iron pyrites or burned with sulphurous coal, trouble from efflorescence is bound to occur, whatever the type of mortar may be, unless the mortar is made practically water proof and a damp proof course of proper materials is built into the wall.

Upon comparing the chemical analysis of lime and cement, it is found that lime contains a substantially less degree of these objectionable salts. The history of lime mortar used in structures which are centuries old amply demonstrates the comparative freedom from efflorescence especially in cases where the lime used was in sufficient quantities and thoroughly ground to form an almost waterproof mortar resulting in the highest type of joint or plaster.

In structures built with bricks and mortar having the objectionable salts referred above and built with poorly filled joints, if the plaster is also a porous one such as a leaner lime mortar than one lime and two sand or cement mortar of one cement and three sand or poorer mix, then, efflorescence is bound to occur. Painting parts of such walls with paints or tar is sometimes resorted to or in some cases rich cement mortar is used for plastering for a few feet height from the ground hoping to drive out efflorescence. In such cases efflorescence is literally driven up and appears above the treated portions of the walls.

Thousands of examples all over the country could be seen where tar or rich cement mortar has been used to cover a part of the basement height of wall and wherein the efflorescence has appeared just above or around such tarred or plastered portions. Such cases are particularly noticed in walls of latrines and around house drainages, where there is ample scope for salts from drainage water to get absorbed into the masonry.

In structures built with granite stone in rich lime mortar, efflorescence is not observed for centuries, because most hard stones do not contain soluble salts. Where efflorescence does

appear in stone masonry ~~it is~~ entirely due to the sand and water used in the mortar. Efflorescence is occasionally seen in pan tiles and flat tiles used in roofs, where it helps in disintegrating and powdering the tiles. In brick masonry pointed with cement mortar, it is sometimes observed that the bricks get powdered and fall loose leaving the lines of cement pointing projecting out. In all such cases the fault is with the clay used for making the tiles and bricks and possibly in the coal used in burning them. Obviously, the covering of masonry built with such poor materials with any kind of plaster cannot remove the causes that go to produce efflorescence in the structure. What a correct type of mortar does when applied as a plaster coat is to prevent moisture from getting into the structure through itself and if the structure does not absorb any water from any other source, efflorescence is prevented.

The best and surest way to minimise efflorescene is to select materials low in soluble salts, construct water-tight masonry and plaster same with relatively water-proof mortar. Lime mortar of one lime and two sand, properly ground, being very plastic, produces a water-tight masonry and the same mortar for plaster produces a waterproof covering for the wall. Such a mortar is more dense and plastic than cement mortar of one

cement and three sand. A cement mortar of one part cement and three or more parts of sand absorbs water especially when used as a plaster for exterior walls of buildings and aids efflorescence instead of preventing it.

Regarding efflorescence, Voss and Henry in their "Architectural Construction, Vol. 1," pages 197–198 say as follows :—

"Efflorescence from brick is due to (a) raw clay, (b) water used in tempering and (c) firing caused by ingredients of the coal ash, sulphur in coal, and pyrites in the clay. Efflorescence from mortar is due to (a) infiltration of soluble salts into the brick, and (b) chemical reactions between the alkalies of the mortar and lime sulphate in the clay."

Surki Mortar.

From the foregoing study, it is seen that lime mortar meets all the requirements, including strength of masonry, for most purposes. However in special circumstances where speed is essential, and there is a demand for a rapid hardening mortar, admixtures of surki (brick dust or fine powder) with lime and sand, called surki mortar, serve the purpose very well. The use of surki overcomes the disadvantages which accompany the use of

fat lime. Surki (brick dust) was highly valued and greatly used by the Ancient Romans, but for several hundred years later its use was not understood and this valuable material fell into disuse. With the greatly extended use of portland cement the importance of surki has again been realised and during recent years the use of it has greatly increased in England and abroad. When portland cement liberates free lime, surki combines with the later and so the freed lime is retained in the mortar. The resulting mortar or concrete is stronger than that in which no surki is used. Surki is no in sense an adulterant, but is on the contrary, a simple means of increasing the strength of concrete and cement mortar. Cement mortars, lime mortars, and concretes containing surki are more water-proof, more resistant to alkalies and to salt solutions than those in which no surki is used. The addition of surki is particularly important in concrete and masonry likely to be subjected to the action of sulphates in solution, *e.g.*, marine structures. (From "The Engineer's Year Book 1944—Kempe.")

Proportions for Surki Mortars.

(Kempe's Engineer's Year Book–1944.)

The best proportions for surki (brick dust) mortars for various purposes are given below :—

Purpose.	Lean lime.	Fat lime.	Lime putty		Surki (brick dust)	Sand.
			Solid.	Fluid.		
A. Water-proof mortars for work which is continuously under water	1	...	...	...	$1\frac{1}{4}$	$1\frac{1}{2}$
		1	...	...	$1\frac{1}{2}$	2
			1	...	3	4
				1	$2\frac{1}{4}$	3
B. Mortars for Quays sluice walls, damp-proof courses, etc.	1	...	...	...	$1\frac{1}{4}$	$2-2\frac{1}{2}$
		1	...	...	$1\frac{1}{2}$	$2\frac{1}{2}-3$
			1	...	3	5 - 6
				1	$2\frac{1}{4}$	$3\frac{3}{4}-4\frac{1}{2}$
C. Mortars for foundations and buildings.	1	...	...	...	$1\frac{1}{4}$	3 — 4
		1	...	...	$1\frac{1}{2}$	4 — 5
			1	...	3	8 — 10
				1	$2\frac{1}{4}$	$6 - 7\frac{1}{2}$

Economic Execution (or Construction Methods)

Economic execution is the determination and adoption of the most economical methods of carrying out the designs of buildings and other projects, *i.e.*, methods by which the immediate and ultimate economy of the nation is conserved to the maximum possible extent. A sharp distinction is to be drawn between false and true economy in construction methods, between spending as little as we can, regardless of the results attained and spending whatever is necessary in order to produce the maximum economic welfare of the people, in short, between spending little and spending wisely.

In the construction of public and private works two systems may be employed, first: the contract system by which men or firms who make a business of construction are employed under some form of contract to undertake the work, second: the daily labour system, in which an organisation consisting of supervisors, maistries, mechanics, craftsmen and labourers is employed and the material purchased by the owner and the work is undertaken independently of contractors.

Each of these systems has its advantages and disadvantages. Each may be entirely satisfactory under certain conditions and very unsatisfactory

under other conditions. The choice of system must depend on the selection of the lesser of two evils when all conditions are considered. The choice should naturally fall on the system which will secure the lowest cost of construction, the best workmanship, promptness of construction and the elimination of contingencies to the greatest degree.

When the nature of the work is such that its character and extent can be accurately defined and when plans and specifications for such work are so prepared that they are clear and complete, the uncertainties are largely removed and contracts given to responsible and experienced contractors are usually satisfactory. When, however, the conditions are indefinite and indeterminate, because of incomplete investigation of conditions or from imperfect and indefinite plans and specifications, any estimate made must be more or less uncertain and will involve a serious risk. Such conditions must result either in exhorbitant rates or the assumption of serious risks at a low price by contractors, who, under such conditions are apt to be more or less inexperienced and irresponsible. In the latter case, especially if the risk assumed by the contractor is realised to his detriment, there is a strong tendency for him to endeavour to recoup his possible losses by furnish-

ing and doing as little as he can under his contract. This often results in disagreements and litigation and quite likely in poor work and general dissatisfaction.

In the lump sum contract the interests of the owner and the contractor are in the main, directly opposed. The owner's desires are as previously outlined. The contractor's interest lies between a desire to obtain maximum profit and to establish or maintain a reputation for honesty, efficiency and ability. The latter desire will induce the responsible contractor to carry out his contract even at a loss but, is insufficient for such purpose with an irresponsible man.

The daily-labour system seems to offer a way of avoiding the difficulties of securing proper work under the contract system. Here, however, the owner exchanges the uncertainty of the honesty, ability and experience of the contractor for similar uncertainties in regard to an organisation which he has to establish for the work at hand, composed of men who are ill-organized for want of responsible labour unions. In many cases, the owner may find that the evils he has assumed are as great as or greater than those which he has elected to avoid.

The problem then is to choose such business methods of construction as will avoid these diffi-

culties as far as practicable. The answer is not apparent and indeed cannot be always the same, for the difficulties in various undertakings are so different that they must be met in each case in a different way and as the circumstances seem to warrant.

Difficulties Met With in Construction

Difficulties to be eliminated, must first be recognised and some of them are briefly outlined below.

The Engineer.

Much depends upon the honesty, integrity, judgment and ability of the engineer employed for carrying out a work. For the best and most economical results, he must be a man who will make the interests of his client and his nation as his own interests so far as equity will permit; his honesty and integrity must be beyond question; his judgment must be developed by knowledge and experience; he must have the ability to design economically and to supervise intelligently the construction proposed; he must have sufficient self-knowledge to recognise his own strength and his own weakness and sufficient character to subdue his personal pride and to demand and secure adequate advice on the subjects on which such advice is needed. An engineer with all such attributes is seldom

available and such qualification can only be approximated. No formulæ can be given for his successful selection. Careful inquiry and observation are the best bases for such selection.

To the contractor, the engineer is an equally important element of uncertainty, especially where local conditions could not be fully known, plans and specifications are incomplete or indefinite, and the contract places large discretionary powers in the hands of the engineer. Is the engineer honest experienced and competent? Is he inexperienced, arbitrary and unfair ? Will he shoulder his own mistakes or will he try to cover his errors, as far as possible, at the contractor's expense ? The answers to these questions would remove one of the greatest difficulties and uncertainties in the cost of the work to the contractor, but unless the contractor has had previous experience under the same engineer, these questions can be answered only by his own experience, as no two contractors seem to exchange correct notes on such matters born out of their personal experience.

Local Conditions.

Complete information covering all the local conditions at which a work is to be carried out, full and complete specifications, a fair contract agreement with provisions for the arbitration of disputed questions will remove much of the

difficulties encountered on account of local conditions. A thorough investigation of local conditions, *e.g.*, nature of soil and sub-soil and water level in foundations at several points in the site should be made and the results of such investigation should be made fully available to those who tender for the work, and the tenderers should also be required to make such additional examination and investigations as will give them a personal knowledge of the conditions involved, so far as practicable.

Plans and Specifications.

Complete and definite plans and specifications should be prepared based on a complete and definite knowledge of the local conditions. They will be indefinite to the extent that the knowledge of the conditions are indefinite and such indefinite plans and specifications will naturally result in high tenders or under certain peculiar circumstances, low tenders and bad work.

Materials.

To obtain all the materials required for a work when needed and at a reasonable price is often a serious difficulty. The cost of transport of the materials from the place of their manufacture or quarry must also be ascertained as a basis for

a correct estimate, and both the cost of materials and their transport may change before the construction is begun. Most of these uncertainties are eliminated if the work has been so designed as to call for the use of materials produced in and around the locality where the work is to be constructed, such as bricks, stone, lime, timber, etc. Enough has been said already about the economics of using local materials and local labour in the design and construction of all structural works, both public and private.

Designing engineers and architects point out that it has become very difficult to secure local material of good quality when needed and at a reasonable price. They forget that it is due to the policy followed by their forefathers in the profession during the past few decades, *i.e.*, the policy of designing works using as far as possible materials made in factories, the local construction industries have been suffocated and many of them have died. It is therefore of vital importance to revive these industries, and for such revival, it is necessary for the state to step in with all the powers at its command by directing that all public works should be designed for the use of construction materials produced by the people of the locality to the maximum possible extent.

In Great Britain in the year 1919 when the building programme was accelerated to an unprecedented pace, both materials and labour were scarce, and therefore, dear. It was at this period many local authorities turned their attention to materials other than the traditional brick, which, however, is still the predominating basis of house construction. The use of cement concrete blocks and poured cement concrete enabled unskilled labour to be employed in the absence of skilled bricklayer.*

The use of cement concrete in Great Britain, however, has never been so widespread as in certain countries, but even there there has been a reversion to brick construction and, in Scandinavia to timber, which is available in plenty in that country.*

Prefabricated steel houses have been the subject of experiment (as well as of jokes and car toons) in the United States for a number of years. The makers claim that such houses need cost a sum ten per cent cheaper than similar timber houses, and that the problem of insulation (a troublesome feature of such houses) has been overcome by a double exterior surface outside the frame with an air space in-between.*

[* From "Town and Country Planning" by Gilbert McAllister and Elizabeth Glen McAllister, 1941].

In Great Britain considerable controversy was arosed when, in 1923, Lord Weir proposed the building of steel houses for the working-classes. Opposition was forthcoming from many quarters. The National Federation of Building Trades Operatives objected strenuously to the competition of engineers and steel manufacturers in the building industry. The general public, including the working classes themselves, looked askance at a new type of dwelling, and although about fifty local authorities took part in the steel house experiment, disputes at Leeds, Sheffield, Glasgow and elsewhere rendered the experiment abortive.*

Experiments, however, continued, and in 1925 Parliament took an important step when it voted £25,000 for the conduct of experiments with new building materials and methods. The Building Research Station at Watford, which has conducted years of valuable work, was the result.*

Materials which have influenced new methods of house construction in recent years include steel (all-steel, steel-frame, block and poured), and timber. The advantages in using new

[* From "Town and Country Planning" by Gilbert McAllister and Elizabeth Glen McAllister, 1941].

materials depend largely on natural supplies in the neighbourhood of construction. Seldom is the cost less than that of brick construction.*

It is for that reason (although many books have been written about changes in building materials) that brick remains the basis of building construction, and particularly, house building in Great Britain.*

Engineers and architects must recognise that there is not a single structure required for the reasonable use of civilsed man that could not be designed with purely local materials. If the engineers and architects are unable to do so, it only shows their bankruptcy in engineering and architectural skill.

Labour.

Similarly with labour. National economy demands that all construction works are built by using local labour as far as practicable.

Skilled and unskilled labour is one of the important items in the cost of construction. The ability to secure suitable men in sufficient numbers for the prompt completion of a work and the ability to correctly foresee the difference in cost of the work if constructed with the help of labour, and machinery, will greatly affect the ultimate cost of construction, and the economy of the people around the site of the work.

When jobs are scarce and hard to find, the men on the work are attentive and efficient; but with plenty of work and labour in demand as during the war time, they become independent and inefficient. The rate of labour increases and the amount of work performed per individual becomes less. These changes occasionally occur after an estimate has been prepared and must be considered as serious uncertainties in all estimates.

A serious problem that affects labour and incidentally, agriculture and food production, is the movement of labour away from the land which has been taking place ever since the first world war of 1914—18. Millions of agricultural workers, discontented with the conditions their forefathers were content to live in, left the land. The farm labourer's son does not want to work on the land : he wants to get to town. Why? Because wages are low and life is dull down in the village, and the house he lives in, while condemned by three generations, is even more intolerable to him than it was to his father. But, apart from all these considerations, he feels the pull of town life. Lights of cities like Madras and Madura are still a strong attraction. And what are the lights of the cities ? – shops, cinemas, coffe-hotels, educational facilities, museums.

A very large proportion of the nervous diseases, and of those cases on the borderland of complete mental breakdown, are primarily attributable to the over-urbanisation of modern life. And yet the rural population continues to drift to the town. Towns people leave the crowded central parts of cities because they want fresh air, houses with gardens, and free access to the countryside. And they go there at infinite expenditure of money on travelling, infinite physical wear and tear, and infinite nervous exhausion, to say nothing of the time lost. Both the townsman and village-man realise that something is missing : the one wants the country, the other wants the town.

Equipment and Machinery.

The satisfactory and economical completion of any work depends upon the prompt supply of the proper equipment, *i.e.*, tools and plant, required for the work. Here a distinction is to be made between the use of essential tools such as crowbars, mamotees, pick-axes, masons and carpenter's tools, etc., which help the labourers and skilled workmen in their daily work and the use of machines such as excavators, conveyors, concrete mixers, towers, etc., which displace the labourers and skilled workmen.

Every engineer and architect who has the interests of his country at heart must recognize the fundamental fact that no country, in which there is unemployment, can afford to engage any kind of labour saving machine without greatly undermining its economy. The history of machinery, its discovery, multiplication and gradual displacement of labour and village industries, resulting in unemployment in every field of human activity, is practically the history of the growth of capitalism. Capitalists, wishing to increase their profits and to free themselves from the responsibilities and worrys accompanying the employment of labour, engage scientists and mechanics to invent machinery for displacing labour in carrying out their works. Thus equipped with machines the capitalists began to wipe the labourers off the face of the earth. They seized on the work done by the handloom weaver in his cottage, and do it much more cheaply in great mills full of expensive machine looms. They raise huge houses of several flats in steel and concrete, so that in place of one horizontal street you have bunches of perpendicular ones. They make yarn by machinery, more of it in a day than ten thousand women could spin by hand. The number of machines in use now has become so numerous, that it is well nigh impossible to think as to how our forefathers carried on their activities for cen-

turies without such machines and whether we can carry on with less machinery at any time in the future.

" Machines were expected to relieve us of mechanical drudgery and give us more time for cultural and artistic pursuits. They have undoubtedly lightened human toil, but have also added somewhat to human drudgery. Modern industrialism based on a minute sub-division of labour has robbed the worker of the sense of craft. Mystery, beauty, and reverence have no place in the workshop. The craftsman has become a mechanic, a mere tool for the ends of greater production. The monotonous piece of work exhausts the body without interesting the mind. The development of intelligence and character which skilful creative work produces is now sought in other activities. The workers seek their pleasure outside their work."*

When it is possible to get plenty of cheep labour, it is criminal to introduce machinery. In several cases of public work wherein the labour was displaced by machines, the engineers responsible for the work have deluded themselves and the statesmen whom they served, into the belief that the cost of the work would be cheapened and the time for completion reduced by carrying out the work

* " Kalki " by Sir S. Radhakrishnan.

with machines A case in point is the Mettur dam in South India, Salem district, where the stone crushing machinery had to be kept idle after only few months use, and two towers of steel for lifting, moving and pouring concrete and the excavators of earth costing more than a crore of rupees, (which is about an eighth of the cost of the whole project) carried out only a fraction of the work for which they were intended and at a great cost, and finally these machinery were sold for almost scrap value. The time taken to complete the project was in no way reduced by the use of these machines either.

The history of all the ancient construction work all over this country down to the end of last century ; such as the Grand anicut, Godavari anicut, Kannambadi dam, arch bridges, palaces, forts and temples, proves beyond any doubt the versatile nature and durability of local materials built with local labour for such monumental works. Modern engineers wonder as to how the ancients built these structures without machines. They cannot conceive for instance, that a piccotah could replace a pump in dewatering deep foundations and at only a fraction of the cost of running and maintaining a pump From the reports on the method of rebuilding the salient angle of the Demibastion at the South-East angle of Fort Saint George, Madras, dated 1846, it is seen that dewatering the deep foundations on the

seaside for rebuilding the wall was done very efficiently and economically by means of the piccotah. It is possible to raise water by piccotahs for about 23 feet and by double piccotahs upto 45 feet. Captain J. T. Smith ends his report of 1846 on this subject with the following words. "From the above data, taking into consideration the prime cost of machinery, the basket scoops will probably be the cheapest, where the quantity of water is limited, and no repetition required ; but for nearly all general purposes in this country, I am of opinion that the piccotah will be found the most efficient "

During the year 1931, I had an opportunity to rebuild an anicut completely from its foundations. It is situated across the Gokivada gedda in Vizagapatam district. The foundations were excavated in the month of March and dewatering the foundation trenches was efficiently done by baskets at a fraction of the cost required for a pump. The foundations and masonry were built of stone in surki mortar.

During the year 1932–33 a similar opportunity occurred in the same district. An arch bridge had to be built across Mogili gedda north of Vizianagaram. The piers and abutments were designed with about 15 feet deep foundations in

the river bed. The foundation trenches were kept clear of subsoil springs by the use of piccotahs and the concrete in foundations was laid.

Incidentally, it may be mentioned that the first design for this bridge was of rolled steel joists and R.C. decking costing Rs. 60,000. Soon after I took charge of the sub-division, I prepared an alternative design consisting of granite stone arches, on masonry piers and macadam road, costing only Rs. 53,000. **Mr. R. P. Mears says in the "Indian Concrete Journal" that the best structures for a bridge to span rivers in India could be built so as to be durable and beautiful, cheaply from purely local materials such as brick, stone, lime and surki.** The arch bridge design was approved and built, affording great relief to the economic condition of the people around the locality. In a village nearby called Pondur, there are about 100 masons and stone cutters. The stone arch bridge engaged all these artisans in its construction. If the rolled steel joist design had been carried out, only a fraction of these artisans would have found employment, and more than half the cost of the bridge would have gone into the pockets of steel, cement and railway magnates. Except for the contractor's profit, all the money spent by the District Board on the stone arch bridge was paid to the people nearby as wages and cost of materials.

To be continually using labour saving machinery, which progressively displaces human labour more and more, is surely the sorriest, and the maddest spectacle that the engineers in this country have ever created in their folly. It is a state of affairs which should make them burn with shame, and make up their minds to end immediately ; it is a cruel and stupid system, which must be changed, so that men may enter on the splendid era of material prosperity and well-being by the revival of all the village construction and other industries.

Some other uncertainties in the final cost of a work are casualties, transportation, supervision, politics, bribery, etc. The form of dishonesty known as bribery is more common to public work than to private work, because the opportunities in public work is greater. It results from private combinations of dishonest men—engineers, supervisors and contractors—who have some influence which can be used to secure the acceptance of high and unfair rates or poor and unfair work or a combination of both resulting in revised estimate for amounts far in excess of the original estimates, and a consequent dishonest profit which may be divided among them. It is a tragedy in construction industry especially in public work, that this disreputable defect in business relations is encountered frequently. Dishonesty is one of the most wasteful and destructive of antisocial vices and its inci-

dence in construction industry has to be considered as another serious uncertainty in all public works estimates.

Economic Management (or Maintenance).

Economic management is the determination of the best methods of maintenance and operation of projects, public works, and factories and the methods by which a new business can best be managed or an old business can be improved, operation costs reduced, and its usefulness increased.

The design and construction of a work decides in many cases the cost of its management and operation. Hence, it is of primary importance to correctly forecast the probable annual cost of maintenance of every alternative design before deciding on the design to be carried out. All the biases and uncertainties enumerated above under economic selection affect the correct estimate of cost of management of any work. It is therefore of the utmost importance for the engineer to recognise his own bias and all the uncertainties that may be encountered, and to provide for them by elimination as far as possible and by the same factors of safety which he applies to the problems of design. To acquire this knowledge is perhaps

the most difficult in the practical education of the engineer.

Economic Expediency.

Economic expediency or the advisability of a project when the best design is considerd for the purpose it is desired to fulfil. This incudes such questions as the advisability of the constuction of the development of irrigation or drinage or other projects ; of the construction of hydro electric plants or power stations to serve certain districts ; of the construction of roads and bridges, or a railroad between certain villages and towns ; and of the purchase or rehabilitation of properties or works already constructed.

Economic Worth.

Economic worth is the determination of the physical, structural and commercial worth or value of a plant or project for the uses and purposes it is intended to fulfil. This includes the question of valuation and appraisal ; the question of the present cash value of public works for purchase, and of private enterprises and manufacturing plants for financial investments and the question of the present and future value of all the tangible and intangible benefits to the public in the case of public works and to the owner in the case of private works and plants.

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In the case of certain types of public works such as roads, bridges, tanks and temples, it is impossible to put an exact money value on the indirect general benefits. But it is certain that such intangible benefits which accrue to the community will have to be taken into account while assessing the economic worth of the project or work. The knowledge, judgment, and experience required for such assessment are much more complex and extended than are required in engineering design or construction.

From the foregoing study it is evident that a thorough study of the problem of economic design and construction at the present time is necessary to effect the revival of all local village industries such as the manufacture of bricks, tiles, lime and pottery and the professions of masonry, carpentry, smithy, sculpture and painting.

The design of all construction works, public and private, with materials produced by village industries and their construction with the labour available in the neighbourhood, is a matter of intimate concern to the engineer; its problems are his problems; its strength is his prosperity and the well being of the people.

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